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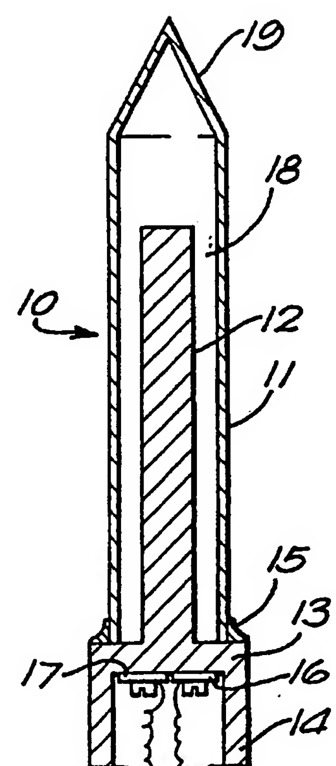
(57) Abstract

A transducer for the measurement of density, viscosity, flowrate or suchlike of fluids or flowable solids comprises a resonator having two vibratile beam elements (11, 12), one of which is disposed coaxially within the other. The outer element (11) may be a closed tube which forms a chamber around the inner element (12). Drive means (16) and sensing means (17) may be disposed on a base (13) which provides a common root for the beam elements.



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TRANSDUCER FOR THE MEASUREMENT OF ATTRIBUTES OF FLOWABLE MEDIA

The present invention relates to transducers for the measurement of attributes of flowable media, for example the density, viscosity, mass flow or the level of a fluid or a flowable solid.

It is known for example from GB-B-2202944 to provide a transducer which essentially comprises a resonator in the general form of a tuning fork for the measurement of attributes of flowable media. The fork is usually constructed from two parallel beam elements of which the longitudinal axes are laterally spaced apart. These beam elements may be tubes which contain the fluid or tines which are immersed in the medium. When tubes are used there is usually a limitation in the size of the bore, limiting the flowrate, and it is usually necessary to provide some means for directing the medium through the tubes, for example a pump. If the device is adapted for insertion into the flowable medium, there is no need for ancillary equipment such as pipe fittings and the transducer can usually be made smaller and easier to install. However, devices employing a pair of tines are susceptible to error or inconvenience arising from the entrapment of debris between the tines, such debris effecting the desired vibration and accordingly the accuracy of measurement.

The invention is generally concerned with the provision of improved and versatile transducers and more particularly an improved transducer which reduces some of the disadvantages associated with a device comprising a pair of spaced apart tines.

The present invention is based on a structure which in preferred forms can be described as a coaxial resonator, for example a resonator composed of two vibratile beam elements having a common base or root, a first of the beam elements being disposed at least partially within the other. In the manner of a tuning fork, when one beam element, for example the outer beam element, is displaced at its distal end, it creates at its base or root a torque moment, which is equalized by the sympathetic movement of the other beam element, there being practically no net displacement at the common base or root. The structure provides a highly efficient vibrating system, having a natural frequency dependent on the physical characteristics, such as the mass and stiffness of the beam elements.

Various other features and aspects of the invention are more conveniently described with the aid of the accompanying drawings.

Brief Description of the Drawings

Figure 1 illustrates in simplified form one embodiment of a transducer according to the invention.

Figure 2 illustrates a second embodiment of a transducer according to the invention.

Detail Description of Preferred Embodiments

Figure 1 illustrates by way of example one embodiment of a transducer according to the invention. This transducer 10 is in the form of a coaxial resonator and comprises two vibratile beam elements, one located inside the other. The outer beam element 11 in this example comprises a tube and the inner element 12 is in the form of a substantially solid tine. Both elements 11 and 12 are either integral with or secured to a base or root 13.

Like a tuning fork, when one beam element, for example the element 11, is displaced or vibrated, it vibrates in the manner of a cantilever beam and accordingly creates at its base or root a torque moment, which is equalized by the sympathetic movement of the other beam element to create practically no resulting displacement at the base or root. The result is an efficient vibrating system with a natural frequency dependent on the mass and stiffness of the elements 11 and 12.

In the present embodiment, the base 13 has a rearwardly extending flange 14 defining a well or partial enclosure wherein an appropriate means for inducing vibration in the resonant structure and for sensing either displacement, strain or other characteristic of the resonant structure may be disposed. This is not the only possible location of such drive means and sensing means but the location specified here is particularly convenient for the structure shown in Figure 1. In this embodiment the drive means is constituted by a piezoelectric plate 16 attached to the underside of the base 13 which provides the common support for the vibrating beam elements and the pickup or sensing means is likewise constituted by a piezoelectric plate 17 similarly disposed on the underside of the base 13.

In the present embodiment, the outer element is closed at its distal end by a nose cone 19. Accordingly, when the transducer is inserted into a fluid, only the external surface of the outer element will be in contact with the fluid. The outer element may therefore be a simple, closed cylinder, having a low propensity for obstructing the flow, resisting insertion or for the entrapment of debris. In such an embodiment, since fluid is not permitted within the chamber 18 inside the outer element, the inner element 12 is free to vibrate without any impedance by the fluid.

When immersed into a fluid or flowable solid, the structure is still capable of acting as a resonator, but the resonant characteristics may be modified by the medium in a variety of ways.

First, as the outer element is displaced during the execution of its natural vibrations, it displaces fluid having a mass proportional to the fluid density. This displacement increases the effective mass of the outer element, resulting in a change of resonant frequency of the transducer. By measurement of this resonant frequency the density of the surrounding fluid may be determined.

Second, as the outer element is displaced during the execution of natural vibration, its surface shears through the fluid, creating a drag force due to viscosity in the outer element. This results in a loss of energy from the vibrating system, manifested by a decrease in the Q (quality factor) of the resonant peak. By measurement of that quality factor, the viscosity of the surrounding fluid may be determined.

Third, if the transducer is so oriented that the longitudinal axis of the outer element is parallel to the flow of the fluid, the transducer causes periodic disturbances normal to the flowing fluid, creating a coriolis force across the length of the tube, in proportion to the mass flowrate. This coriolis force can be measured as a variation in oscillatory phase of the outer element, the measurement being capable of providing an indication of the coriolis acceleration and accordingly the mass flowrate.

Fourth, if the outer element is only partially covered by the external fluid, it will vibrate at a frequency proportional to the amount of covering fluid in a fluid density. The fluid density can be established from a second, fully covered, vibrating element, so that the

resonant frequency is a function of fluid cover or level. The outer element might be short, such as only ten centimetres, or long, such as ten metres, to embrace the variation required to measure different levels.

In a similar way to that just described, the transducer may be used as a level switch. The frequency of vibration in air or a vacuum can be established. The presence of small quantities of material on the surface of the outer element can result in a change of the natural frequency of vibration. By monitoring the resonant frequency of the apparatus, one may indicate the presence or absence of material. This configuration of the device is applicable to the detection of non-fluid matter such as particulate solids.

The resonant structure may be driven into sustained vibration from a periodic energy source in the appropriate phase and frequency relationships with a mechanical displacement of the vibrating elements. The drive means may be electromagnetic, acoustic, or capacitative, or operate by deformation of piezoelectric devices bonded at some appropriate point, as shown in Figure 1, and driven using a periodically varying electrical signal. The vibration may be sensed by a variety of techniques which create an electrical signal in response to a displacement or strain at a mechanically efficient point in the apparatus. As noted in the foregoing, Figure 1 illustrates the use of a piezoelectric element as a vibration sensor at the base of the apparatus, but many other forms of sensor may be employed.

The structure can be driven into continuous oscillation by the use of a gain limiting amplifier and the suitable matching of phase between drive and pickup transducers. Feedback from the sensing transducer may be used for this purpose.

Further embodiments of the invention may employ inner and outer elements driven at higher cantilever modes of vibration and combinations thereof. For example, the outer element may be tuned to vibrate at its second or third mode whereas the inner element can be maintained at a fundamental mode. The selection of modes may be based on a choice of mass or stiffness characteristics of the two elements so that there is no resultant displacement at the base of the apparatus or otherwise. Vibration of the outer element at a higher mode can create greater sensitivity of measurement and improve immunity to variation in mounting conditions at the base.

Figure 2 illustrates an embodiment similar to that shown in Figure 1, using a fixed or removable extension to the outer element. Those parts of Figure 2 which are common to the embodiment of Figure 1 are denoted by the same reference numbers are will not be described again. In the embodiment of Figure 2, the outer tube 11 has a flat end cap 20, which carries a vane 21 constituting an extension to the vibrating structure.

If the vane 21 were disposed in a plane normal to the vibration, it would increase the surface area disturbing the fluid and therefore improve the sensitivity of density measurement. If the vane were disposed at right angles to the position shown, so that it were parallel to the plane of vibration, it would increase the shear surface and thereby improve sensitivity in the measurement of viscosity.

The vibrating elements may be elliptical, square, or polygonic in cross-section in accordance with different effects of the section on the measurement of different attributes.

Further embodiments of the invention may include a port, for example in the base 13, allowing fluid to flow into the

chamber 18 between the inner and outer elements to equalize the pressure on the outer element and reduce any pressure stress thereon.

Further modifications to the disclosed embodiments are feasible. For example, the transducer may be incorporated into a system having more than two elements. It may be advantageous to mount the base on a semi-rigid bellows or other means which provides at least some mechanical decoupling between the transducer and a structure to which it may be attached.

CLAIMS

1. A transducer for the measurement of attributes of flowable media, comprising a resonator comprising two vibratile beam elements (11,12) having a common base, characterised in that one of the said two beam elements (12) is disposed at least partially within the other of the said two beam elements.

2. A transducer according to claim 1 wherein at least an outer one (11) of the said two beam element comprises a tube.

3. A transducer according to claim 2 wherein the outer beam element (11) is closed at a distal end remote from the base so as to define a chamber around the inner element (12) of the said two beam elements.

4. A transducer for the measurement of attributes of flowable media, comprising a resonant structure including two laterally spaced elements extending from a common support, characterised in that the said two elements (11,12) have longitudinal axes which are substantially coincident.

5. A transducer according to claim 4 wherein one of the transducers is disposed at least partly within the other.

6. A transducer according to any foregoing claim, and including drive means (16) for inducing vibration of the beam elements.

7. A transducer according to any foregoing claim, and including means (17) for sensing at least one attribute of the vibration of the elements.

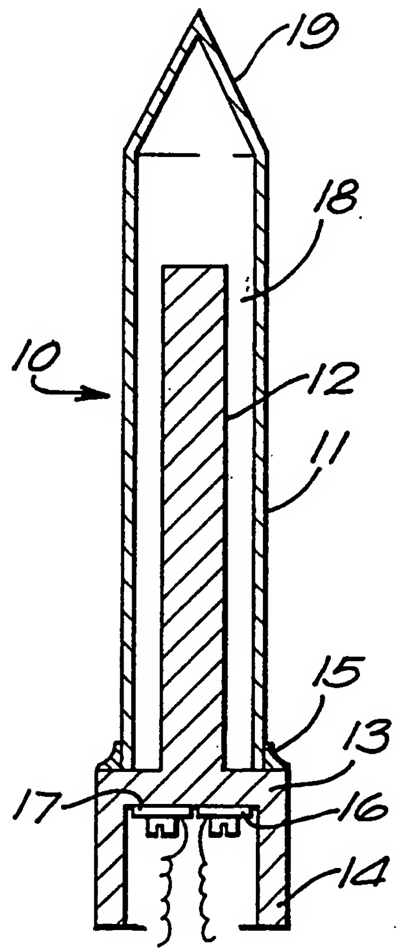

FIG.1

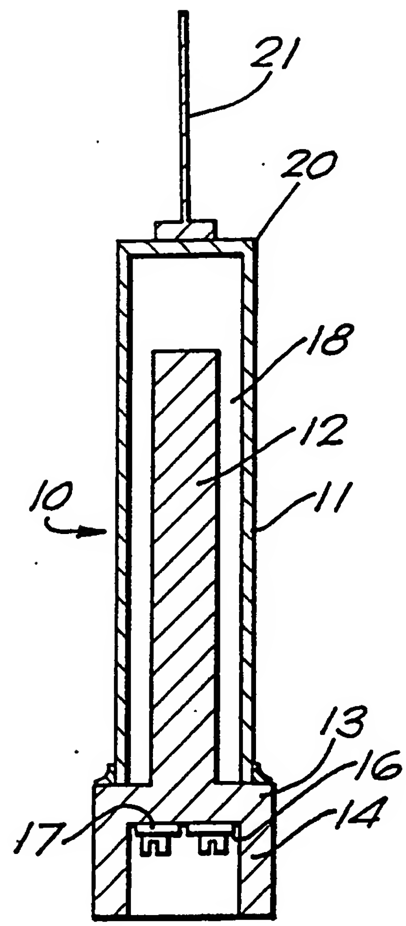

FIG.2

INTERNATIONAL SEARCH REPORT

Inte· ·onal Application No
PCT/GB 93/02453

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 G01N9/00 G01F23/28 G01F1/84 G01N11/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 G01N G01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO,A,83 01307 (VEGA GRIESHABER GMBH) 14 April 1983 see page 2, line 15 - line 28 see page 6, line 3 - line 17; figures 1,2 ---	1-7
A	ELECTRONIC ENGINEERING vol. 53, no. 659 , November 1981 , LONDON GB pages 159 - 168 LANGDON 'vibratory process control transducers' see page 167, line 1 - line 17 see page 168, column 1, line 15 - line 32 --- -/--	1,4

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
21 February 1994	4. 03. 94

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Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 282 251 (SCHLUMBERGER) 14 September 1988 cited in the application see column 3, line 10 - line 42; figure 1 see column 3, line 50 - line 58; figure 2 see column 8, line 26 - column 10, line 17 ---	4-7
X	US,A,4 740 726 (UMEZAWA) 26 April 1988 see column 2, line 41 - column 3, line 16; figures 2,4 ---	1-7
P,X	EP,A,0 564 682 (ENDRESS+HAUSER FLOWTEC AG) 13 October 1993 ---	1-7
A	US,A,3 625 058 (ENDRESS ET AL.) 7 December 1971 -----	1,4

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte[r]nal Application No
PCT/GB 93/02453

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
WO-A-8301307	14-04-83	EP-A,B	0089336	28-09-83
		US-A-	4499765	19-02-85
EP-A-0282251	14-09-88	DE-A-	3878473	25-03-93
		GB-A,B	2202944	05-10-88
		JP-A-	63308528	15-12-88
		US-A-	4922745	08-05-90
US-A-4740726	26-04-88	DE-A-	3734077	20-04-89
		GB-A-	2210689	14-06-89
EP-A-0564682	13-10-93	NONE		
US-A-3625058	07-12-71	DE-A-	1773815	03-02-72
		CH-A-	491370	31-05-70
		FR-A-	2012618	20-03-70
		GB-A-	1250537	20-10-71
		NL-A-	8103934	04-01-82
		NL-A-	8103935	04-01-82
		NL-A-	6905224	13-01-70
		SE-B-	376652	02-06-75